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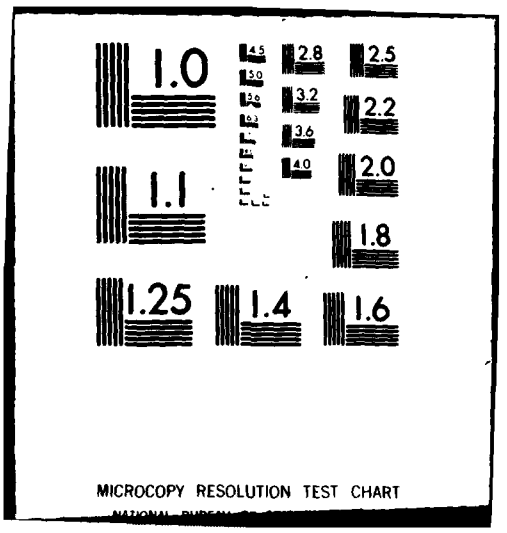
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FINAL REPORT

Grant No. AFOSR-77-3379

FLOW LEADING TO FRACTURE

P. P. Gillis and S. E. Jones, Co-Principal Investigators

ABSTRACT

The research objectives are stated and the degree to which they have been accomplished is discussed. A list of publications and conference presentations is given which correlates the level of accomplishment with the research objectives.

RESEARCH OBJECTIVES

The purpose of the research was to establish a theoretical basis for the forming limit diagram. The effects of strain rate sensitivity and phase stability on formability were to be assessed as accurately as possible. In addition, whatever other factors that seem significant, for example, imperfection sensitivity, were to be included in the proposed analysis. The research was to be conducted primarily on a theoretical basis, invoking experimental results already published wherever possible but performing new experiments whenever necessary.

STATUS OF THE RESEARCH EFFORT

Activity on the project was sharply focussed on the principal research objectives: to establish a theoretical basis for the

forming limit diagram. Formidable algebraic difficulties impeded this effort and it was not until the end of the second year that the first satisfactory theoretical development was completed (and reported in Informal Letter Progress Report No. 9). This theory accounts for biaxial stretching which comprises the right half of the forming limit diagram, and accounts for the effects of strain rate sensitivity on material behavior. However, it cannot be applied to the left half of the diagram (longitudinal stretching with transverse contraction) in any direct way. So, much work remains to be done in the basic theoretical formulation.

Numerical results calculated on the basis of the above theory were not entirely satisfactory. This led to an examination of the material flow law being used and this law was shown to have certain fundamental defects. Reformulation of the flow law led to preparation of a manuscript entitled "A Generalized Quadratic Flow Law for Sheet Metals". Numerical results calculated on the basis of the above theory incorporating the reformulated flow law are quite satisfactory. They are being incorporated in a manuscript entitled "Biaxial Stretching of a Flat Sheet".

PUBLICATIONS

Efforts expended on this project have led to publication of the following seven papers and three abstracts.

"Tensile Deformation of a Round Bar", by P. P. Gillis and S. E. Jones, Journal of Engineering Mathematics 12 365 (78).

"A Criterion for Plastic Instability", by S. E. Jones and P. P. Gillis, Formability: Analysis, Modeling and Experimentation, S. S. Hecker, A. K. Ghosh and H. L. Gegel, Eds. AIME (1978) p. 46.

"Tensile Deformation of a Flat Sheet", by P. P. Gillis and S. E. Jones, International Journal of Mechanical Sciences, 21 109 (1979).

"Analyses of Necking in a Viscoplastic Bar", by S. E. Jones, P. P. Gillis and A. H. Shalaby, (Abstract) Proceedings of the 15th Annual Meeting of the Society of Engineering Science, 1978, page 479.

"Stress Distributions in the Vicinity of a Neck", by S. E. Jones, P. P. Gillis and A. H. Shalaby, Journal of Applied Physics, 50 3168 (1979).

"A Note on Tensile Deformation of Flat Sheets", by S. E. Jones, A. H. Shalaby and P. P. Gillis, International Journal of Mechanical Sciences, 22 325 (1980).

"Sheet Necking Under Biaxial Stretching", by S. E. Jones and P. P. Gillis, (Abstract) Proceedings of the 16th Annual Meeting of the Society of Engineering Science, 1979, page 169.

"A Generalized Quadratic Flow Law for Sheet Metals", by S. E. Jones and P. P. Gillis, submitted for publication to the International Journal of Mechanical Sciences.

"Approximate Analysis of In-Plane Stretching of Sheet Metals with

Special Emphasis on Forming Limit Diagrams", by P. P. Gillis and S. E. Jones, (Abstract) accepted for publication in the Proceedings of the 17th Annual Meeting of the Society of Engineering Science, 1980.

"Biaxial Stretching of a Flat Sheet", by S. E. Jones and P. P. Gillis, in final preparation for submission for publication to the International Journal of Mechanical Sciences.

The principal thrust of the above publications has been to replace criteria for small plastic instabilities with analyses of large instabilities. An important exception is the paper on stress distributions in round-bar necks which constitutes a three-dimensional extension of the classic analysis from which the Bridgman correction factor derives.

PROFESSIONAL PERSONNEL

The professional staff who were involved in this project during the report period and their approximate degrees of effort were as follows:

Peter P. Gillis, Professor of Materials Science
Dept. of Metallurgical Engineering and Materials Science
10% of 2 academic years, 80% of 4 summers.

Stanley E. Jones, Associate Professor of Engineering Mechanics

Department of Engineering Mechanics

20% of 2 academic years, 100% of 4 summers.

Abdel H. Shalaby, Research Associate

Department of Metallurgical Engineering and

Materials Science

85% of 2 calendar years

No advanced degrees were earned under sponsorship of this project during the report period.

INTERACTIONS

Spoken papers presented at meetings or conferences as a result of efforts expended on this project were as follows:

"A Criterion for Plastic Instability", presented by P. P. Gillis at the Fall Meeting of TMS-AIME, in Chicago, October 1977.

"The Influence of Strain Rate Sensitivity on Superplastic Deformation", presented by S. E. Jones at the Annual Meeting of the AIME, in Denver, February 1978.

"Approximate Analyses of Tensile Plastic Instabilities", presented by S. E. Jones at the Eighth U. S. National Congress of Applied Mechanics in Los Angeles, July 1978.

"Tensile Deformation of a Flat Sheet", presented by S. E. Jones at the Eighth U. S. National Congress of Applied Mechanics in Los Angeles, July 1978.

"Stress Distributions in the Vicinity of a Neck", presented by S. E. Jones at the Fall Meeting of the Metallurgical Society of AIME, St. Louis, Missouri, October 1978.

"Analyses of Necking in a Viscoplastic Bar", an invited presentation by S. E. Jones at the 15th Annual Meeting of the Society of Engineering Science, Gainesville, Florida, December 1978.

"Sheet Necking Under Biaxial Stretching", an invited presentation by P. P. Gillis at the 16th Annual Meeting of the Society of Engineering Science, Evanston, Illinois, September 1979.

"Modeling Forming Limit Diagrams for Sheet Metals", an invited Department of Engineering Sciences Seminar by S. E. Jones at the University of Florida, Gainesville, Florida, February 1980.

"Approximate Analysis of In-Plane Stretching of Sheet Metals with Special Emphasis on Forming Limit Diagrams", an invited presentation to be made by P. P. Gillis at the 17th Annual Meeting of the Society of Engineering Science, Atlanta, Georgia, December 1980.

In addition Prof. Jones chaired the Plasticity Analysis Session TB at the Eighth U. S. National Congress of Applied Mechanics. Also, Prof. Gillis and Prof. Jones attended the Physical Metallurgy

Gordon Research Conference on strain localization during plastic deformation held in Andover, New Hampshire during July 1979.

No consultative or advisory activities were undertaken involving the federal government beyond those informal discussions that occured at technical meetings.

NEW DISCOVERIES, ETC.

No inventions, patent disclosures or specific applications arose from this research effort during the report period. The principal developments have been the partial theory of the forming limit diagram enunciated in Informal Letter Progress Report No. 9 and the formulation of a more generalized quadratic flow law both of which eventually will be published in the open literature.

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PHASE STABILITY
FORMABILITY

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Activity on the project was sharply focused on the principal research objectives; to establish a theoretical basis for the forming limit diagram. Formidable algebraic difficulties impeded this effort and it was not until the end of the second year that the first satisfactory theoretical development was completed. This theory accounts for biaxial stretching which comprises the right half of the forming limit diagram, and accounts for the effects of strain rate senitivity on material behavior. However, it cannot be applied to the left half of the diagram (longitudinal stretching with transverse → next page

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contraction) in any direct way. So much work remains to be done in the basic theoretical formulation. Numerical results calculated on the basis of the above theory were not entirely satisfactory. This led to an examination of the material flow law being used and this law was shown to have certain fundamental defects. Reformulation of the flow law led to preparation of a manuscript entitled "A Generalized Quadratic Flow Law for Sheet Metals." Numerical results calculated on the basis of the above theory incorporating the reformulated flow law are quite satisfactory. They are being incorporated in a manuscript entitled "Biaxial Stretching of a Flat Sheet".